STEERING FOR BEAM CENTERING AT THE LOW-β^* INTERACTION POINT

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In the Jostlein method of beam centering[1,2] the colliding beams trace out a transverse circular motion relative to each other. This note describes an example of the steering that is required by this technique for the CDR lattice.[3]

The appropriate angular deflections produced by a particular combination of correction dipoles near the interaction point have been determined for a 1 micron parallel displacement of both beams in the horizontal and vertical directions at the low-β^* interaction point. The locations of the correction dipoles have been taken from the CDR Figure 5.11-3, reproduced as Figure 1 here. Table I summarizes the results in terms of angular deflections and bending power. Beam 2 is a mirror image of Beam 1 except that the horizontal and vertical corrections and deflections are exchanged.

Table I. Deflections and Bending Power for 1 Micron Transverse Motion.

Horizontal Deflections, Beam 1				Vertical Deflections, Beam 1			
Distance from IP, meters	Angular deflection, nanoradians	BL Gauss-meters	I milli-amps	Distance from IP, meters	Angular deflection, nanoradians	BL Gauss-meters	I milli-amps
-376	35.5	23.7	75	-403	0.0	0.0	0
-306	0.0	0.0	0	-342	0.0	0.0	0
-271	39.9	26.7	84	-271	3.2	2.1	7
-76	24.6	16.4	52	-76	24.6	16.4	52
76	24.6	16.4	52	76	24.6	16.4	52
271	3.2	2.1	7	271	39.9	26.7	84
342	0.0	0.0	0	306	0.0	0.0	0
403	0.0	0.0	0	376	35.5	23.7	75

Corresponding beam trajectories are shown in Figures 2 and 3 in which the numbers associated with the beam elements give the required angular deflections in nanoradians. Table II lists the same information in tabular form. In this scheme the maximum displacement occurs in the focusing plane of QV just before Q4. It is 3.8 microns for an IP displacement of 1 micron. If the second correction bend in that plane is increased, the beam can be brought back to the nominal center line at the next correction element. Then a final correction bend of about 70 nanoradians would be required and the maximum displacement would be closer to 3 microns. Other schemes are of course possible and, given the modest bending power requirements, different locations independent of the standard correction elements could also be selected. The 1.8 micron displacement in Q2 (for 1 micron at the interaction point) is unavoidable, however.

The standard correction dipoles produce 3.18 T-m at 100 amperes. For a 1 micron amplitude in transverse beam displacement the largest current amplitude in the above scheme is below 100 ma. The coil inductance of the correction dipole is 1.4 H. If, for example, a 1 kHz frequency is desired for the Jostlein scheme a tuned circuit with a 30,000 pf capacitor could easily be used in an efficient and simple control circuit arrangement.

A sobering comparison can be made between the entries in Table I and the total deflection in the BV3 vertical bending-magnet string which is 3,124,500 nanoradians. The largest deflection amplitude for the 1 micron Jostlein displacement amplitude is thus about one part in 10^{-5} of BV3. However, the method is precisely designed to correct for errors at about this level.[2]

Table II. Low-β^* Elements and Trajectory for 1-μ Displacement.

Element	Length (m)	Position (m)	x (μ)	x' (nr)	y (μ)	y' (nr)
#bv+	0.00	-403.50	0.00	0.00	0.00	0.00
dspoo	0.50	-403.00	0.00	0.00	0.00	0.00
vspool-4	0.00	-403.00	0.00	0.00	0.00	0.00
dspoo	0.50	-402.50	0.00	0.00	0.00	0.00
#qdv	0.00	-402.50	0.00	0.00	0.00	0.00
qdv	7.55	-394.95	0.00	0.00	0.00	0.00
oovsp2	18.91	-376.05	0.00	0.00	0.00	0.00
hspool-3	0.00	-376.05	0.00	35.53	0.00	0.00
oovsp1	1.00	-375.05	0.04	35.53	0.00	0.00
qfv	7.55	-367.50	0.29	31.54	0.00	0.00
#qfv	0.00	-367.50	0.29	31.54	0.00	0.00
qfv	7.55	-359.95	0.50	21.92	0.00	0.00
ov4sp2	18.29	-341.67	0.90	21.92	0.00	0.00
vspool-3	0.00	-341.67	0.90	21.92	0.00	0.00
ov4sp1	1.00	-340.67	0.92	21.92	0.00	0.00
qd4	8.16	-332.50	1.21	49.05	0.00	0.00
#qdr	0.00	-332.50	1.21	49.05	0.00	0.00
qd4	8.16	-324.33	1.75	86.75	0.00	0.00
ov4sp2	18.29	-306.05	3.34	86.75	0.00	0.00
hspool6	0.00	-306.05	3.34	86.75	0.00	0.00
ov4sp1	1.00	-305.05	3.42	86.75	0.00	0.00
qfv	7.55	-297.50	3.75	-0.61	0.00	0.00
#qfv	0.00	-297.50	3.75	-0.61	0.00	0.00
qfv	7.55	-289.95	3.41	-87.87	0.00	0.00
oovsp2	18.91	-271.05	1.75	-87.87	0.00	0.00
vspool-2	0.00	-271.05	1.75	-87.87	0.00	3.21
hspool-2	0.00	-271.05	1.75	-47.96	0.00	3.21
oovsp1	1.00	-270.05	1.71	-47.96	0.00	3.21
qdv	7.55	-262.50	1.49	-10.24	0.03	2.85
#qdv	0.00	-262.50	1.49	-10.24	0.03	2.85
dv2	26.00	-236.50	1.22	-10.24	0.10	2.85
#bv-	0.00	-236.50	1.22	-10.24	0.10	2.85

Element	Length (m)	Position (m)	x (μ)	x' (nr)	y (μ)	y' (nr)
bv-	8.00	-228.50	1.14	-10.24	0.12	2.85
d	1.00	-227.50	1.13	-10.24	0.13	2.85
bv-	8.00	-219.50	1.05	-10.24	0.15	2.85
#bv-	0.00	-219.50	1.05	-10.24	0.15	2.85
dv1	123.00	-96.50	-0.21	-10.24	0.50	2.85
#bv+	0.00	-96.50	-0.21	-10.24	0.50	2.85
bv+	8.00	-88.50	-0.29	-10.24	0.52	2.85
d	1.00	-87.50	-0.30	-10.24	0.52	2.85
bv+	8.00	-79.50	-0.39	-10.24	0.55	2.85
#bv+	0.00	-79.50	-0.39	-10.24	0.55	2.85
d3sp	2.99	-76.51	-0.42	-10.24	0.56	2.85
vspool-1	0.00	-76.51	-0.42	-10.24	0.56	27.45
hspool-1	0.00	-76.51	-0.42	14.37	0.56	27.45
d3sp	2.99	-73.52	-0.37	14.37	0.64	27.45
qf3	6.52	-67.00	-0.26	21.08	0.87	43.13
#qf3	0.00	-67.00	-0.26	21.08	0.37	43.13
qf3	6.52	-60.48	-0.10	24.93	1.21	64.82
o	0.80	-59.68	-0.08	24.93	1.26	64.82
qd2	5.89	-53.78	0.06	24.71	1.57	37.86
#qd2	0.00	-53.78	0.06	24.71	1.57	37.86
qd2	5.89	-47.89	0.21	27.26	1.70	6.73
o	0.80	-47.09	0.23	27.26	1.71	6.73
qd2	5.89	-41.20	0.41	33.28	1.65	-25.23
#qd2	0.00	-41.20	0.41	33.28	1.65	-25.23
qd2	5.89	-35.30	0.63	43.03	1.42	-54.42
o	0.80	-34.50	0.67	43.03	1.37	-54.42
qf1	7.25	-27.25	0.91	23.56	1.09	-24.98
#qf1	0.00	-27.25	0.91	23.56	1.09	-24.98
qf1	7.25	-20.00	1.00	0.00	1.00	0.00
d0	20.00	0.00	1.00	0.00	1.00	0.00
#ip–	0.00	0.00	1.00	0.00	1.00	0.00

Table II. (Continued)

Element	Length (m)	Position (m)	x (μ)	x' (nr)	y (μ)	y' (nr)
#ip-	0.00	0.00	1.00	0.00	1.00	0.00
d0	20.00	20.00	1.00	0.00	1.00	0.00
1qd	7.25	27.25	1.09	24.98	0.91	-23.56
#1qd	0.00	27.25	1.09	24.98	0.91	-23.56
1qd	7.25	34.50	1.37	54.42	0.67	-43.03
o	0.80	35.30	1.42	54.42	0.63	-43.03
2qf	5.89	41.19	1.65	25.23	0.41	-33.28
#2qf	0.00	41.19	1.65	25.23	0.41	-33.28
2qf	5.89	47.09	1.71	-6.73	0.23	-27.26
o	0.80	47.89	1.70	-6.73	0.21	-27.26
2qf	5.89	53.78	1.57	-37.86	0.06	-24.71
#2qf	0.00	53.78	1.57	-37.86	0.06	-24.71
2qf	5.89	59.68	1.26	-64.82	-0.08	-24.93
o	0.80	60.48	1.21	-64.82	-0.10	-24.93
3qd	6.52	67.00	0.87	-43.13	-0.26	-21.08
#3qd	0.00	67.00	0.87	-43.13	-0.26	-21.08
3qd	6.52	73.52	0.64	-27.45	-0.37	-14.37
d3sp	2.99	76.51	0.56	-27.45	-0.42	-14.37
hspool1	0.00	76.51	0.56	-2.85	-0.42	-14.37
vspool1	0.00	76.51	0.56	-2.85	-0.42	10.24
d3sp	2.99	79.50	0.55	-2.85	-0.39	10.24
#bv+	0.00	79.50	0.55	-2.85	-0.39	10.24
bv+	8.00	87.50	0.52	-2.85	-0.30	10.24
d	1.00	88.50	0.52	-2.85	-0.29	10.24
bv+	8.00	96.50	0.50	-2.85	-0.21	10.24
#bv+	0.00	96.50	0.50	-2.85	-0.21	10.24
dv1	123.00	219.50	0.15	-2.85	1.05	10.24
#bv-	0.00	219.50	0.15	-2.85	1.05	10.24
bv-	8.00	227.50	0.13	-2.85	1.13	10.24
d	1.00	228.50	0.12	-2.85	1.14	10.24
bv-	8.00	236.50	0.10	-2.85	1.22	10.24
#bv-	0.00	236.50	0.10	-2.85	1.22	10.24

Element	Length (m)	Position (m)	x (μ)	x' (nr)	y (μ)	y' (nr)
dv2	26.00	262.50	0.03	-2.85	1.49	10.24
#qfv	0.00	262.50	0.03	-2.85	1.49	10.24
qfv	7.55	270.05	0.00	-3.21	1.71	47.96
oovsp1	1.00	271.05	0.00	-3.21	1.75	47.96
hspool2	0.00	271.05	0.00	0.00	1.75	47.96
vspool2	0.00	271.05	0.00	0.00	1.75	87.87
oovsp2	18.91	289.95	0.00	0.00	3.41	87.87
qdv	7.55	297.50	0.00	0.00	3.75	0.61
#qdv	0.00	297.50	0.00	0.00	3.75	0.61
qdv	7.55	305.05	0.00	0.00	3.42	-86.75
ov4sp1	1.00	306.05	0.00	0.00	3.34	-86.75
vspool3	0.00	306.05	0.00	0.00	3.34	-86.75
ov4sp2	18.29	324.33	0.00	0.00	1.75	-86.75
4qf	8.16	332.50	0.00	0.00	1.21	-49.05
#4qf	0.00	332.50	0.00	0.00	1.21	-49.05
4qf	8.16	340.67	0.00	0.00	0.92	-21.92
ov4sp1	1.00	341.67	0.00	0.00	0.90	-21.92
hspool3	0.00	341.67	0.00	0.00	0.90	-21.92
ov4sp2	18.29	359.95	0.00	0.00	0.50	-21.92
qdv	7.55	367.50	0.00	0.00	0.29	-31.54
#qdv	0.00	367.50	0.00	0.00	0.29	-31.54
qdv	7.55	375.05	0.00	0.00	0.04	-35.53
oovsp1	1.00	376.05	0.00	0.00	0.00	-35.53
vspool4	0.00	376.05	0.00	0.00	0.00	0.00
oovsp2	18.91	394.95	0.00	0.00	0.00	0.00
qfv	7.55	402.50	0.00	0.00	0.00	0.00
#qfv	0.00	402.50	0.00	0.00	0.00	0.00
dspoo	0.50	403.00	0.00	0.00	0.00	0.00
hspool4	0.00	403.00	0.00	0.00	0.00	0.00
dspoo	0.50	403.50	0.00	0.00	0.00	0.00
#bv+	0.00	403.50	0.00	0.00	0.00	0.00

REFERENCES

1. H. Jostlein, Fermilab Report TM-1253 (1984).
2. Donald H. Stork, Central Design Group Report SSC-N-198 (1985).
3. Conceptual Design of the Superconducting Super Collider, SSC Central Design Group, March, 1986.

FIGURE CAPTIONS

1. "Low-beta interaction region orbit correctors. Control of the crossing angle and beam separation is provided by a set of 6 correction dipoles in each plane together with a system of position monitors." (CDR Figure 5.11-3.)
2. Horizontal trajectories for beams displaced by 1 micron parallel to their nominal position. A vertical section of the beam lines is shown on the same longitudinal scale. Values of horizontal angular deflection in nanoradians are given as labels for each horizontal correction dipole.
3. Vertical displacement equivalent of Figure 2.

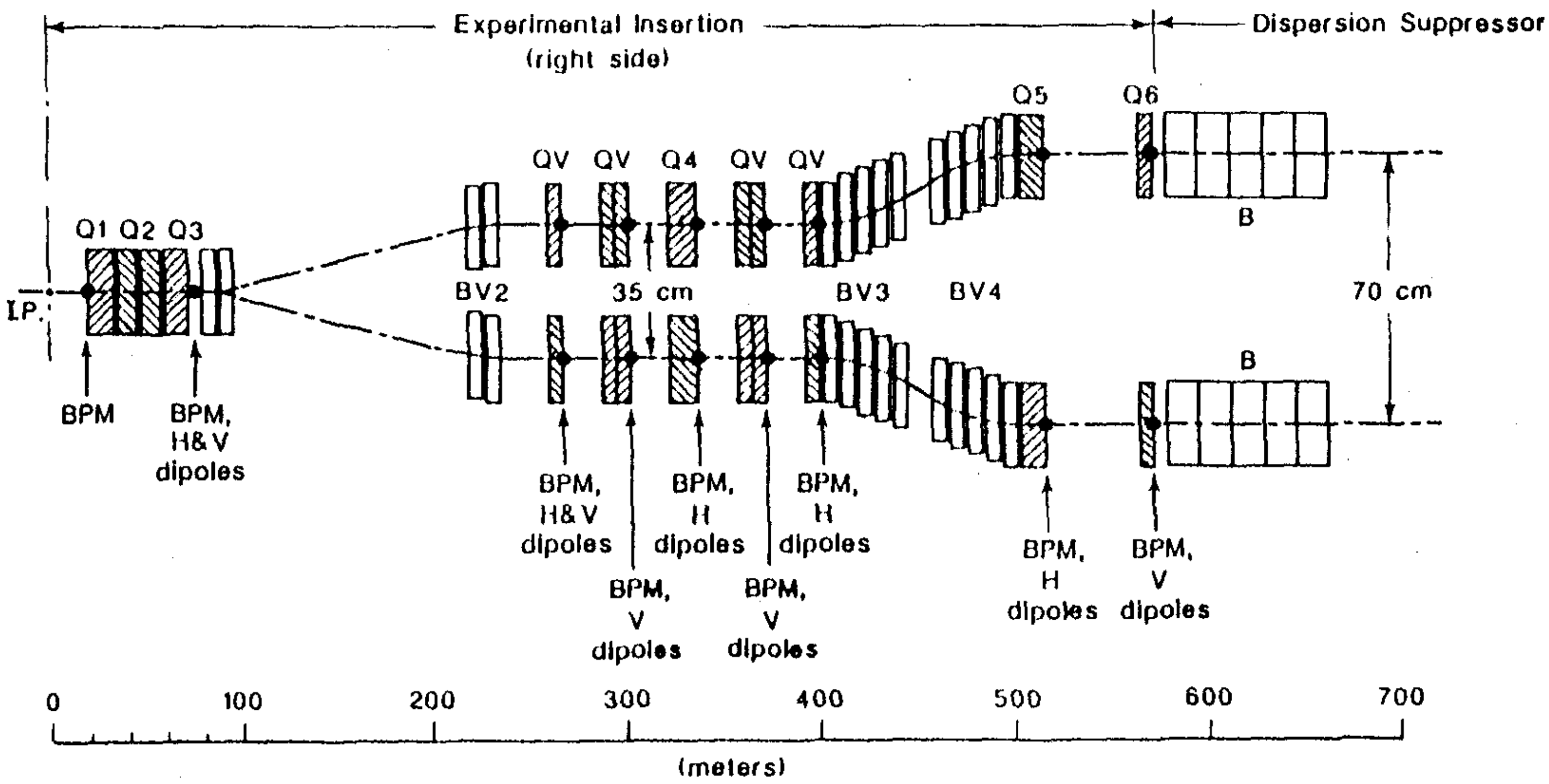

Experimental Insertion
(right side)
Dispersion Suppressor
Q1 Q2 Q3
QV QV Q4 QV QV
Q5
Q6
B
I.P.
BV2
35 cm
BV3
BV4
70 cm
BPM
BPM, H&V dipoles
BPM, H&V dipoles
BPM, V dipoles
BPM, H dipoles
BPM, V dipoles
BPM, H dipoles
BPM, H dipoles
BPM, V dipoles
0
100
200
300
400
500
600
700
(meters)

Figure 1.

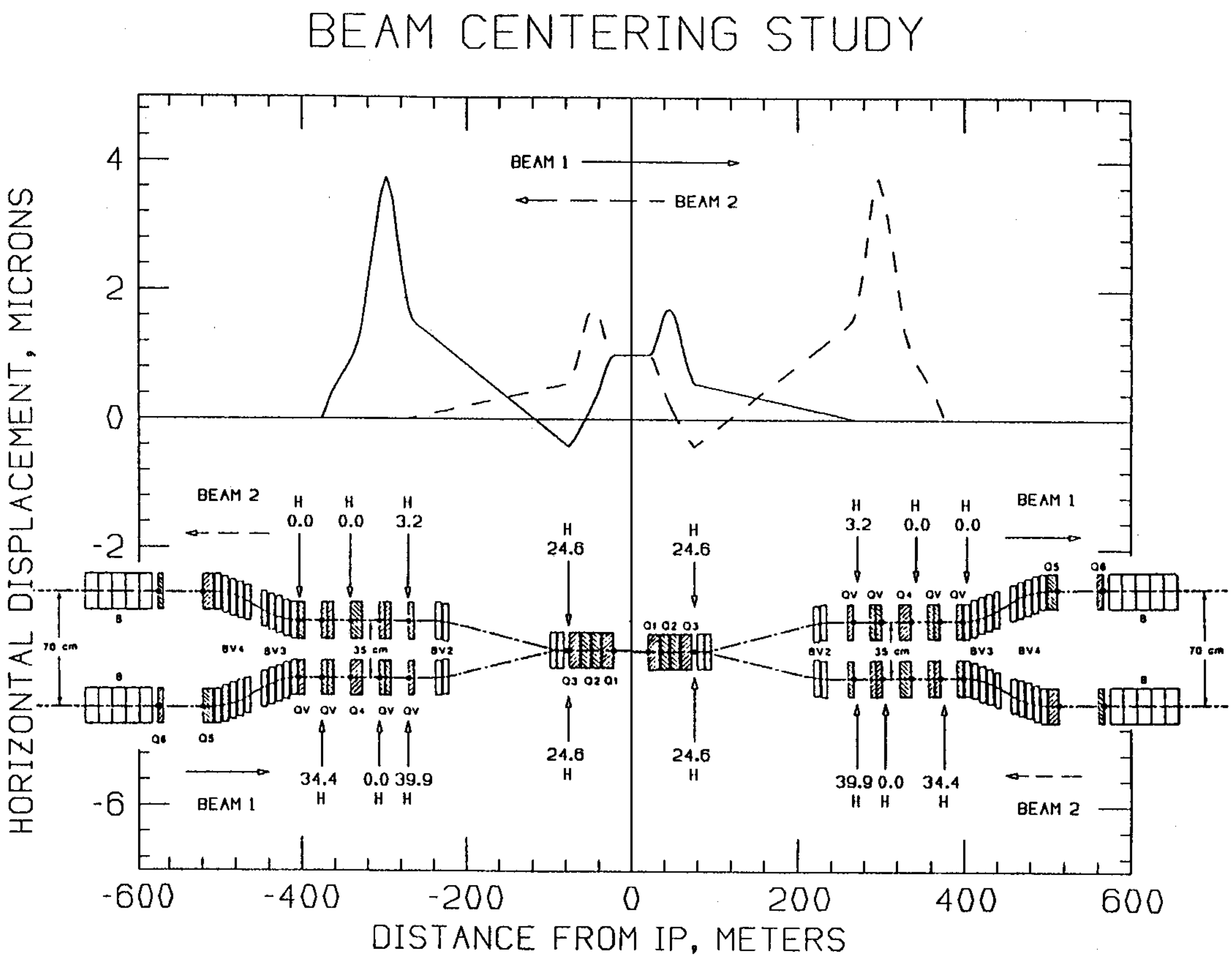
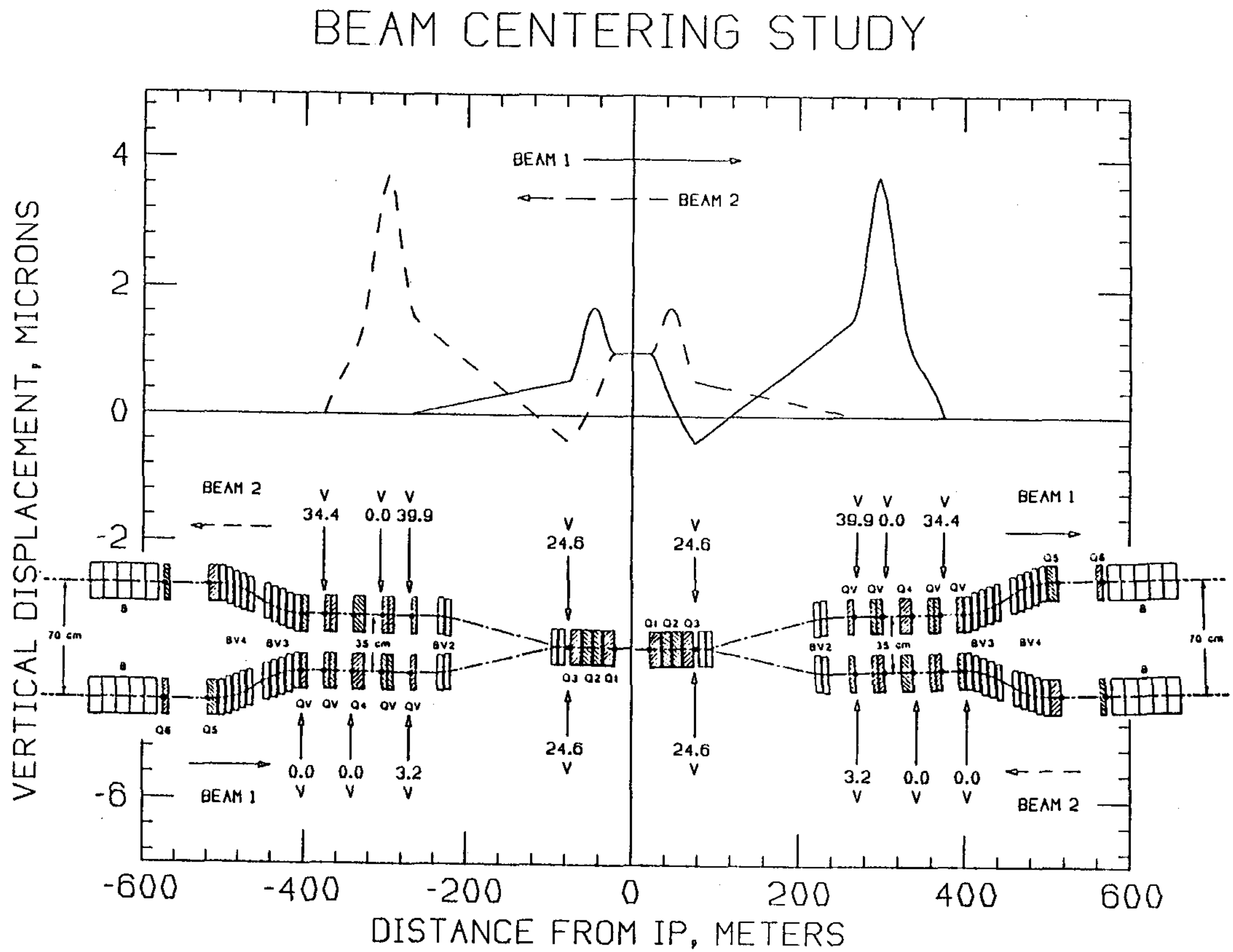

BEAM CENTERING STUDY
HORIZONTAL DISPLACEMENT, MICRONS
DISTANCE FROM IP, METERS
4
2
0
-2
-6
-600
-400
-200
0
200
400
600
BEAM 1
BEAM 2
H 0.0
H 0.0
H 3.2
H 24.6
H 24.6
H 3.2
H 0.0
H 0.0
24.6 H
24.6 H
34.4 H
0.0 H
39.9 H
39.9 H
0.0 H
34.4 H
BEAM 1
BEAM 2
BEAM 1
BEAM 2
70 cm
70 cm
35 cm
35 cm
Q1 Q2 Q3
Q3 Q2 Q1
QV QV Q4 QV QV
BV2
BV3
BV4
Q5
Q6
B

Figure 2.



BEAM CENTERING STUDY
BEAM 1
BEAM 2
VERTICAL DISPLACEMENT, MICRONS
DISTANCE FROM IP, METERS
4
2
0
-2
-6
-600
-400
-200
0
200
400
600
V 34.4
V 0.0
V 39.9
V 24.6
0.0 V
3.2 V
24.6 V
Q1 Q2 Q3
Q4
Q5
Q6
QV
B
BV2
BV3
BV4
35 cm
70 cm

Figure 3.